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PREPRINT

Micropower Ultra-Wideband Radar

T. E. McEwan

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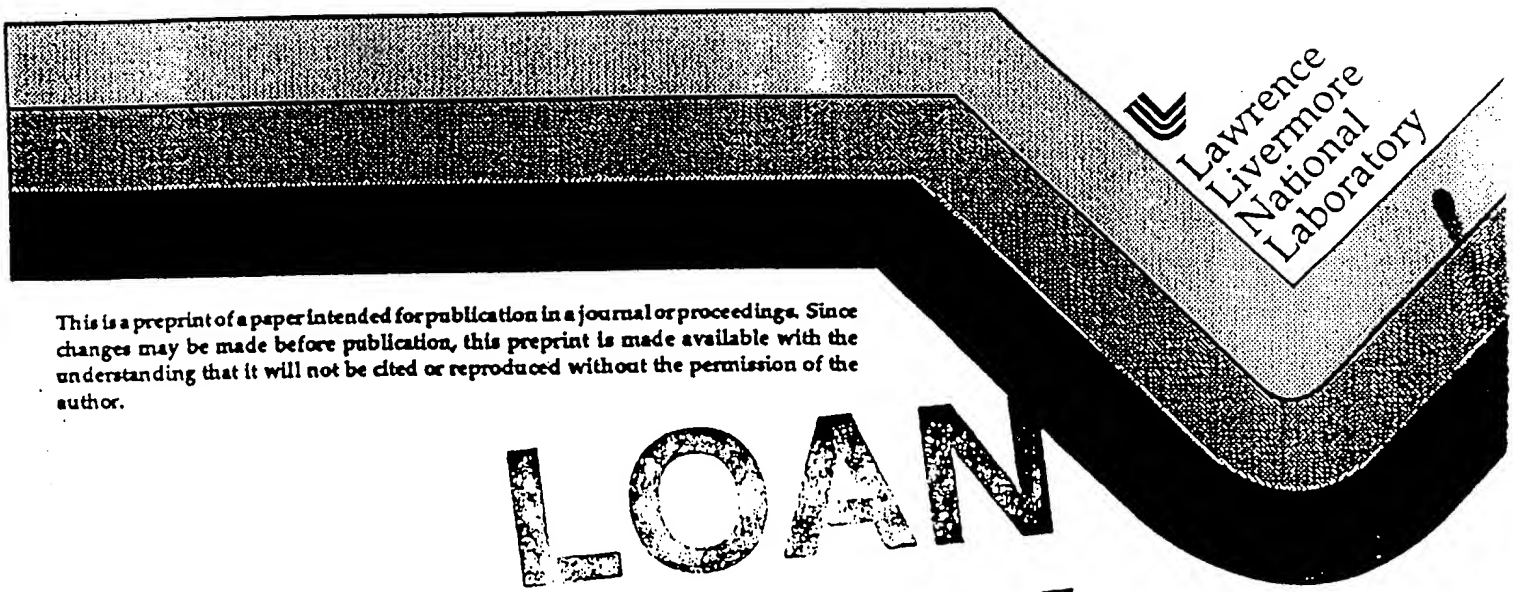


DISCLAIMER

1993 R&D 100 Award Entry Form Data

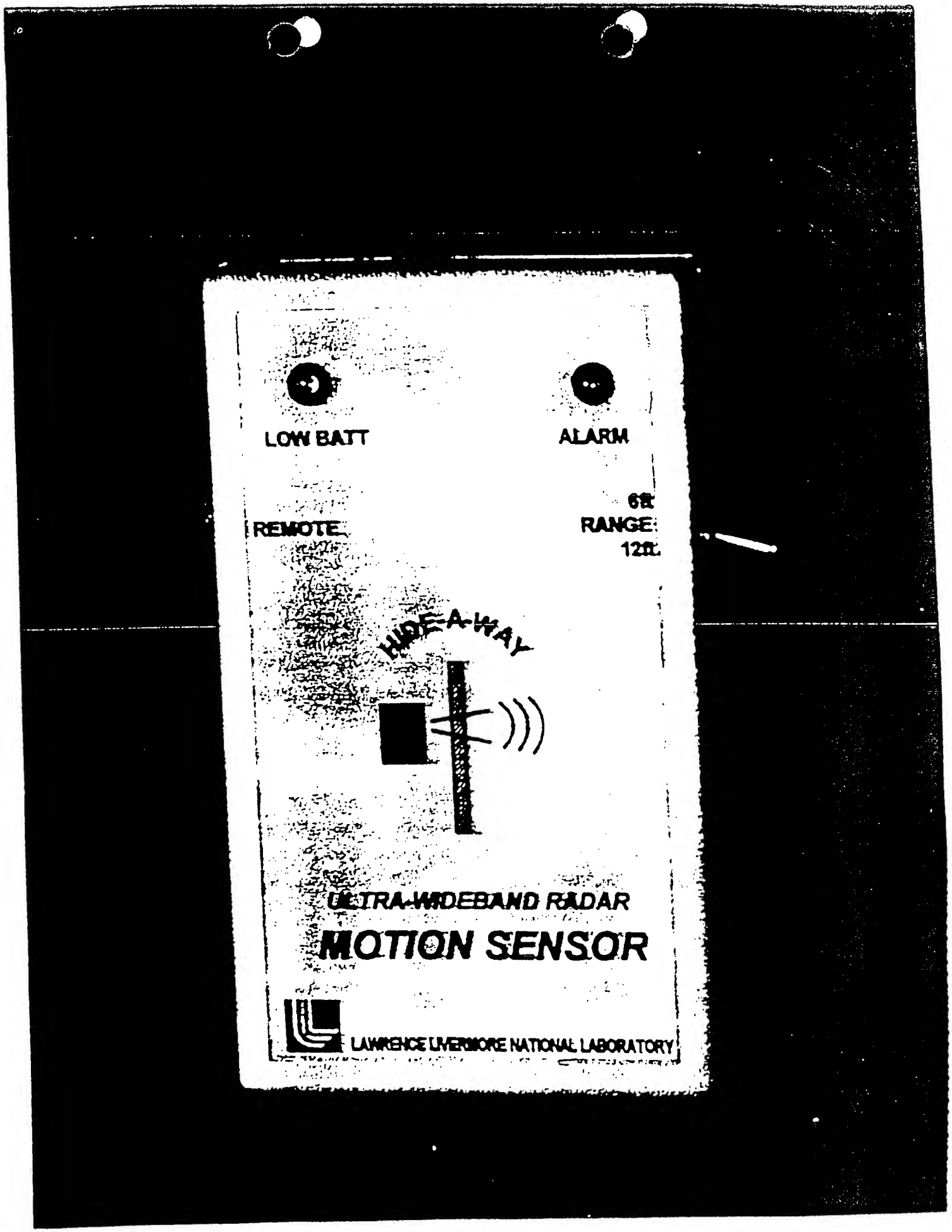
Micropower Ultra-Wideband Radar

Lawrence Livermore National Laboratory

Thomas E. McEwan
Inventor

A new paradigm in radar technology has been developed that will usher in a cornucopia of entirely new and exciting consumer products. We present two products with near-magical properties.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.



Radar [illegible] projects a sharply defined, invisible detection "bubble" through walls

Official Entry Form
1993 R&D 100 Award Competition
(Please fill out names of organizations, products, and developers as you would want them listed in R&D Magazine.)

1. **Name of submitting firm or organization:**
Parent company: Lawrence Livermore National Laboratory
Division or subsidiary: Y Division
Address: P.O. Box 808, L-479 (7000 East Avenue)
City, State, Zip: Livermore, CA 94550
Country: USA Phone: 510/422-1621 FAX: 510/294-6793

2. **Joint entry with:** A) _____ Contact person: _____
Address _____ City _____ State _____ Phone: _____
B) _____ Contact person: _____
Address _____ City _____ State _____ Phone: _____
List full addresses of joint firms in item 13. If more than 2 joint firms check here ( )

3. **Product description:**
A. Brand name or model number of entry: Micropower ultra-wideband (UWB) radar

B. Briefly describe what the entry is (e.g., gas chromatograph, refinement process, conductive fabric, etc.):
We present two entirely new products based on a new paradigm in radar technology: an intrusion detector that can see through walls, and an impulse radar wall stud finder.

4. When was this product first marketed or available for order? Month 11 Year 92 (Must be first available in 1992. See instructions under "Eligibility".)

5. Inventor or principal developer of this product or process (Use care in answering this question. No more than three persons will be named in competition results. More than that will be listed as "a research team"):
A. Name: Thomas E. McEwan Position: Engineer
Company: Lawrence Livermore Laboratory Division: Lasers/EE
Address: P.O. Box 808, L-479 (7000 East Avenue)
City, State, Zip: Livermore, CA 94550
Country: USA Phone: 510/422-1621 FAX: 510/294-6793
B. Co-developer: _____ Position: _____
Company: _____ Division: _____
Address: _____
City, State, Zip: _____
Country: _____ Phone: _____ FAX: _____

Company: _____ Division: _____

Address: _____

City, State, Zip: _____

Country: _____ Phone: _____ FAX: _____

6. List the price of this product per marketing unit (specify). Note that not providing a price may suggest to the judges that your product is not available for sale or license and consequently may disqualify your entry. If the price is proprietary, list it and check here. ( ) $ 20 per (unit) sensor

7. A. To whom should reader inquires about your product be directed ?

Name: Thomas E. McEwan Position: Engineer

Company: Lawrence Livermore Laboratory Division: Lasers/EE

Address: P.O. Box 808, L-479 (7000 East Avenue)

City, State, Zip: Livermore, CA 94550

Country: USA Phone: 510/422-1621 FAX: 510/294-6793

8. This entry form is being submitted by:

Name: Thomas E. McEwan Position: Engineer

Company: Lawrence Livermore Laboratory Division: Lasers/EE

Address: P.O. Box 808, L-479 (7000 East Avenue)

City, State, Zip: Livermore, CA 94550

Country: USA Phone: 510/422-1621 FAX: 510/294-6793

AFFIRMATION: I affirm that all information submitted as a part of, or supplemental to, this entry presents a fair and accurate representation of this product.

(Signature of submitter) T. E. McE

ALL ENTRIES MUST BE SIGNED

are involved? Limit your answer to one page of double-spaced copy. Supplemental material may be presented in an appendix.

See attachment

9. Is this product a unique entry to the marketplace that is not directly competitive with existing products?

YES( ) NO( )

See attachment

A. If your product is not unique, identify its competitors by manufacturer, brand name, and model number.

B. Describe how your product improves upon competitive products. It is very important that this question is answered as completely and accurately as possible since it provides a major basis for determining whether your entry justifies an R&D 100 Award.

BE SPECIFIC! Include such items as (*how much faster, how much less cost, etc.*) Failure to include such information may permit the judges to overlook an important advantage. Your answer to this question must be limited to one page of double-spaced copy. Expanded discussion can be included in an appendix.

10. A. Describe the principal applications of this product.

B. List all other applications for which your product can now be used.

C. List all applications that you foresee will be possible for your product in the future. Indicate why these applications are not now feasible.

See attachment

11. State briefly why--in terms of significant technological innovation--you feel your product should receive an R&D 100 Award. Why is it important to have this product? What benefits will it provide? State your answer in simple laymen's terms. (The value of the award for its prestige, promotional value, or reward to the developer(s) is understood, and need not be mentioned.) Limit your answer to one page of double-spaced copy.

See attachment

NON-PRODUCT INFORMATION

12. Names and addresses of joint developers (from item 2):

A. Co-developing parent company:_____

Division or subsidiary:_____

Address:_____

City, State, Zip:_____

Country:_____ Phone:_____ FAX:_____

B. Co-developing parent company:_____

Division or subsidiary:_____

Address:_____

City, State, Zip:_____

Country:_____ Phone:_____ FAX:_____

13. A. Do you hold any patents on this product? YES( ) NO(X)

B. Do you have any patents pending? YES(X) NO( )

C. Do others hold patents on this product or a similar product line? YES( ) NO(X)

If yes, please specify._____

R&D

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Please complete all questions in th... If your entry wins an R&D 100 Award, d...ied addresses will expedite our communications with your organization.

14. A. Who is the contact person in your organization to handle all arrangements on exhibits, banquet, and publicity?
Name: John F. Holzrichter Position: Director of IR&D
Company: Lawrence Livermore Laboratory Division:
Address: P.O. Box 808, L-3
City, State, Zip: Livermore, CA 94550
Country: USA Phone: 510/423-7454 FAX:

B. Chief Executive Officer (corporate or university president, government research center director, etc.)
Name: John H. Nuckolls Position: Laboratory Director
Company: Lawrence Livermore Laboratory Division:
Address: P.O. Box 808, L-1
City, State, Zip: Livermore, CA 94550
Country: USA Phone: 510/422-5435 FAX:

C. Research Director:
Address:
City, State, Zip:
Country: Phone: FAX:

D. Advertising Manager:
Address:
City, State, Zip:
Country: Phone: FAX:

E. Public Relations Director: Charles H. Biederman
Address: P.O. Box 808, L-404 (7000 East Avenue)
City, State, Zip: Livermore, CA 94550
Country: USA Phone: 510/423-3100 FAX:

After completing this entry form, refer to the instructions page, 'Entry Procedure,' to be sure that nothing has been left out. Also, see entry checklist.

ABOUT THE AWARDS PROGRAM

The R&D 100 Awards program is the only competition in the world that recognizes the 100 most technologically significant new products of the past year.

This international competition—celebrating its 31st year—has a twofold purpose:
- To recognize innovators and organizations for outstanding practical technical developments.
- To identify significant technological advances.

You are invited to enter those new technical products that you consider to be significant developments. "Technical products" is broadly defined to include any product, material, process, software, program, or system of scientific or technical origin or use.

ELIGIBILITY

Any new technical product that was first marketed between Jan. 1, 1992, and Dec. 31, 1992, may be entered. Products that will not be mass-produced must have become available for contract or licensing during that period, or—in special instances—completed and delivered by a government agency or laboratory during that period.

"Proof-of-concept" models of a "breadboard" or optical-bench nature are viewed skeptically by the judges and probably should not be entered until they are developed to a more-advanced stage.

Physical existence of the product must be shown in the form of a photograph of an actual sample or process. Software entries should have descriptive screen shots or diskettes or the equivalent.

8. **What is the primary function of the product.** Micropower impulse radar-wideband (UWB) radar sensing is an entirely new sensor technology. It is a based on the pulse-echo radar principle of clocking the two-way time of flight of an electromagnetic pulse, but differs from conventional radar in that a sub-nanosecond voltage pulse is applied directly to a broadband antenna. The broad spectral content of the pulse is freely radiated without frequency up-conversion or an RF carrier. Oscillators, mixers and tuned circuits are thereby eliminated, and without up-conversion the radiated spectrum appears low on the absorption curve of most materials.

For motion detection, the micropower UWB radar stares at a fixed range or set of ranges, and senses any change in radar reflectivity at that range (Fig. 1). When used with a wide coverage antenna, a thin spherical range cell or "invisible bubble" about an inch thick is projected into space. The radius of the bubble is set by a simple timing adjustment from several inches to several hundred feet, depending on the application and user preference. If an object pierces the bubble, the average radar cross section (RCS) changes and produces a response. Fig. 2 shows the response when a human hand is inserted into and removed from a radar bubble. Also shown is the slight attenuation introduced by locating the sensor behind 2" of concrete or 6" of textbooks.

Micropower implementation is possible since most of the circuitry is normally "off" except for the brief instant that an impulse is being transmitted - typical duty cycle is <10ppm and power draw for a home security intrusion detector is 3V at 90 microamps. Micropower operation also results in low emission levels, about one microwatt average, well below OSHA safety limits. Since emissions are spread across several gigaHertz bandwidth, power spectral density falls below the thermal noise floor of radios and TVs located outside the maximum detection range. Extremely low duty cycle and a high level of pulse averaging also ensure that co-located sensors never interfere with each other.

9. **Is the product a [redacted] entry to the marketplace.** No

a) **Identity of competitors.** 1) PIR motion sensors: one example is the X-10 Powerhouse #SP554 wireless PIR sensor.

2) StudFinder: sole competitor is Zircon's "StudSensor"

b) **Improvements upon competitive products.**

Motion Sensor: Passive infrared (PIR) motion sensors are the mainstay of the security alarm industry. They are micropower, of low cost, and have good range and area coverage. Unfortunately, PIR (and ultrasound) is totally blocked by even a sheet of paper and thus cannot be concealed. Further, there is no specific range limit, just a sensitivity adjustment. The UWB radar motion sensor (Fig. 3, cover photo) easily operates through walls and can be concealed for reasons of security, cosmetics or installation convenience. In addition, its sharply defined, user adjustable range can be used to eliminate false alarms. For example, the UWB sensor can be placed above a ceiling with its detection "bubble" set to reach down to intercept humans but not pets. UWB sensors can also be configured for omni-directional coverage; several such sensors located in closets or above ceilings can provide complete home coverage. Combined with a radio link, micropower UWB sensors can provide instant security protection of high value equipment (Fig. 4) with no installation required.

StudFinder: Zircon's wall stud locator senses changes in wall dielectric density and thus depends directly on dielectric constant. Generally, it operates only on gypsum walls. The UWB radar StudFinder (Figs. 5&6) propagates a pulse that is less materials-dependent by the square root of dielectric constant. It works well on both gypsum and various woods. Further, the dielectric sensor fails to operate if there is a slight air gap between it and the wall, due to the large change in electric field distribution. The propagating pulse of the UWB StudFinder easily spans air gaps and is uniquely effective on textured walls and sprayed-on ceilings. The UWB StudFinder also alerts the user to the presence of metal, which may be dangerous to nail into. See the attached Appendix for a feature comparison.

10a. Principal applications.

Intrusion detection for home security systems is an immediate market with a one billion dollar sales potential. The outstanding features provided by UWB radar motion sensing combined with its low cost will rank UWB side-by-side with PIR sensors in popularity.

The UWB radar StudFinder is another immediate application that will address a surprisingly large market. A Wall Street Journal article (Dec. 1992) hailed the dielectric-sensing StudSensor as "the most successful electronic tool ever" with over 9 million units sold, or approximately $180M total. The UWB radar StudFinder is a highly competitive entry into this market.

10b. Other applications include:

- concealed light switches
- traffic flow monitoring
- proximity activated toys
- aids for the handicapped
- curb and blind spot sensing for vehicles
- subsurface pipe and wire location

UWB circuits may also drive laser diodes for range-gated pencil beams or "light sabers".

10c. Future applications. UWB radar sensors are perfect for homes of the future. Sleek interior designs with "smart walls" will use between-wall UWB sensors to replace the common wall light switch and door knob. Combined with a computer, smart walls will also provide home security and child monitoring services. Appliances fitted with behind-panel UWB proximity sensors will open doors, turn on lights, or stop running at the approach of a hand.

Since UWB radar sensors require no inductors or frequency tuning elements, they are fully integrateable onto a single silicon chip. Using currently available technology, a complete radar sensor can be fabricated for about one dollar per chip .

11. **Micropower UWB radar sensors are winning products because** they offer an exciting spectrum of features:

- ability to see through walls and instrument panels
- user adjustable, sharply-defined detection "bubble"
- several year battery life
- inductorless, tunerless operation - single chip integrateable
- simple construction with common components
- very low retail price for consumer products (~$20)
- a vast untapped potential.

The development of micropower UWB radar required a major departure from conventional wisdom. Virtually all R&D work on UWB radar, specifically impulse radar, has focused on the development of megawatt impulse sources, special antennas and feed circuits, and elaborate test facilities. Only a few papers have surveyed the problem of receiving sub-nanosecond pulses, and none have suggested the possibility of building a UWB radar at low cost. UWB receivers are based on expensive transient digitizers or wideband sampling scopes, and UWB transmitters are generally based on costly 1-100kV sub-nanosecond pulsers.

The receiver used in our micropower UWB radar is based on a transformerless sampling circuit of a new design (pat. pend.) that can detect one microvolt, 100ps pulses - well below the level of any scope. Rather than taking the low repetition rate, high peak power approach that the UWB community has focused on, these sensors place sufficient energy on target by integrating low peak power, high repetition rate pulses. Combined with new systems-level techniques for motion sensing (pats. pend.) we have brought forth a remarkable new sensor technology.

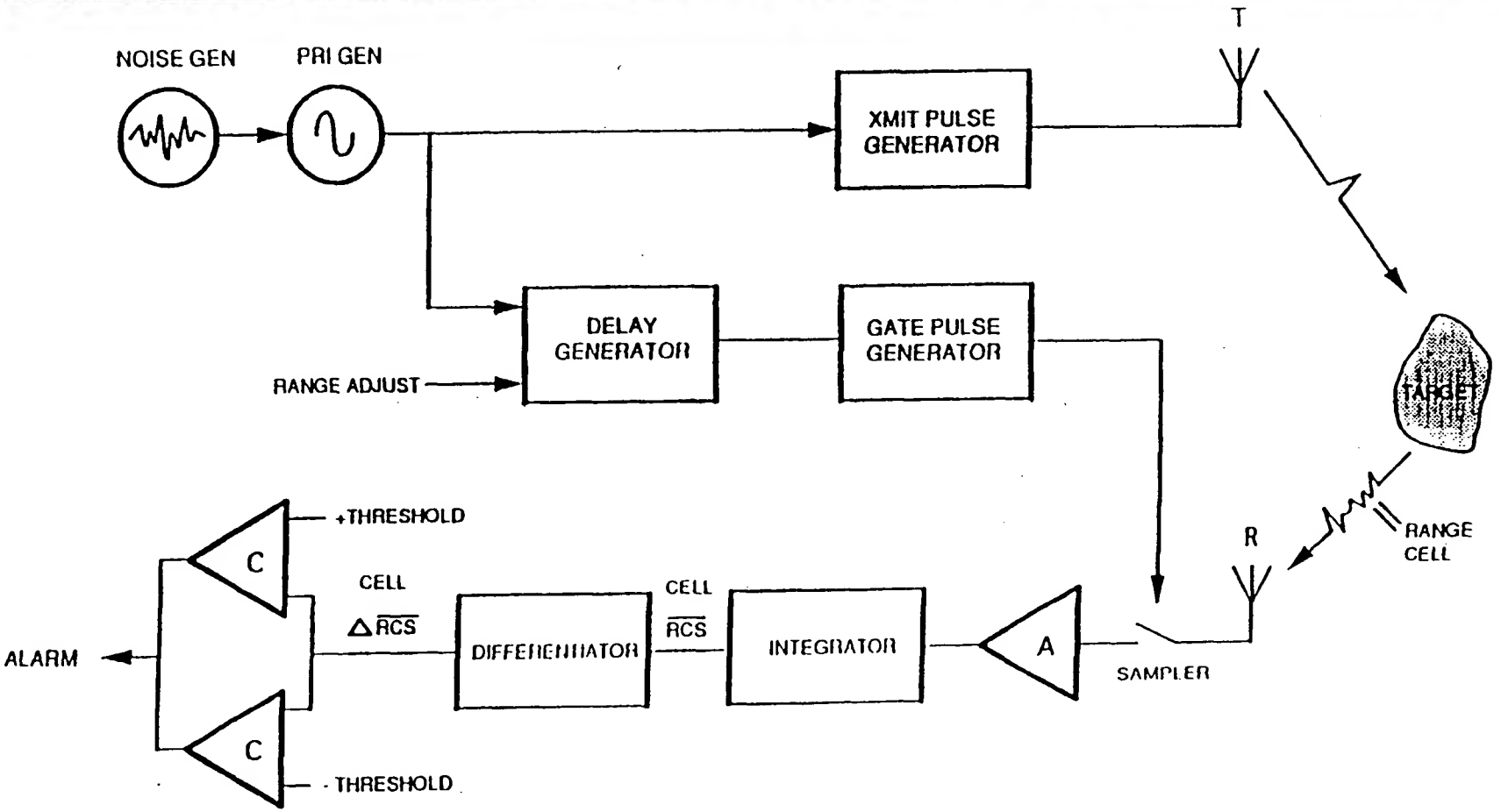
Micropower UWB radar sensors are a new paradigm in radar technology that will foster a wealth of new products

APPENDIX
STUDFINDER FEATURE COMPARISON

	Dielectric Sensor	Impulse Radar
1. Detects studs behind gypsum	yes	yes
2. " plywood	no	yes
3. " particle board	no	yes
4. " hardwood	no	yes
5. " floor boards and tiles	no	yes
6. Useable on furniture and cabinetry	no	yes
7. Operates non-contact (sprayed-on ceilings)	no	yes
8. Accurately indicates edge of stud	no	no
9. Accurately indicates center of stud	yes	yes
10. Indicates metal	no	yes
11. Battery life	18 hrs	41 hrs
12. Sensitivity independent of battery age	no	yes
13. Low battery indicator	no	yes
14. High brightness multicolored LEDs	no	yes
15. FCC Part 15 compliant	yes	yes
16. Retail price (estimated 1993 dollars)	$20	$20

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48

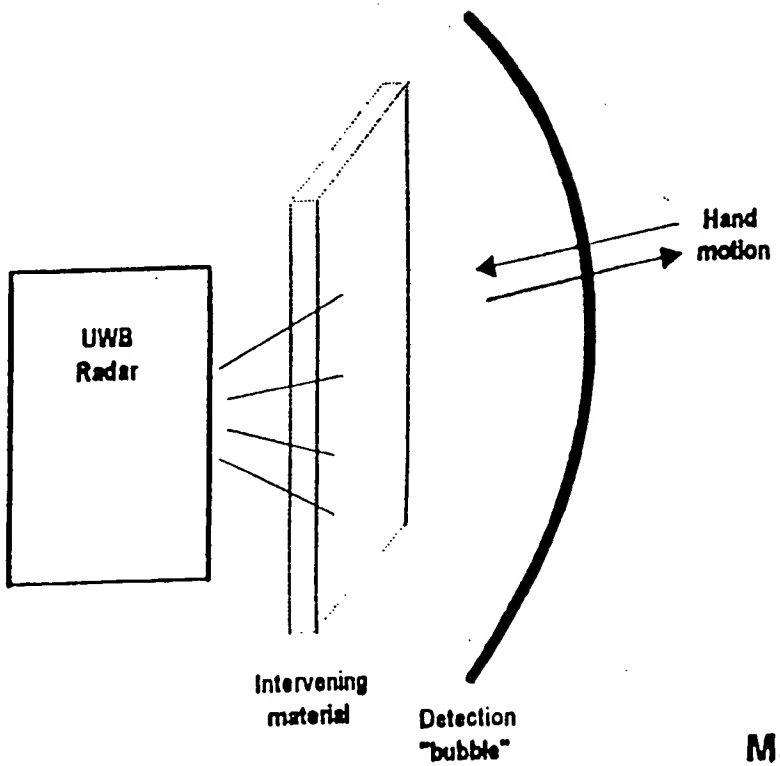
The UWB Radar Motion Sensor Detects Changes in Radar Reflectivity in a Range Cell



- One or more range cells are repetitively sampled and averaged
- A range cell forms an invisible detection "bubble" in space
- The "bubble" is ~1" thick and easily adjustable in range

The UWB Radar Motion Sensor Penetrates Thick Materials with Little Attenuation

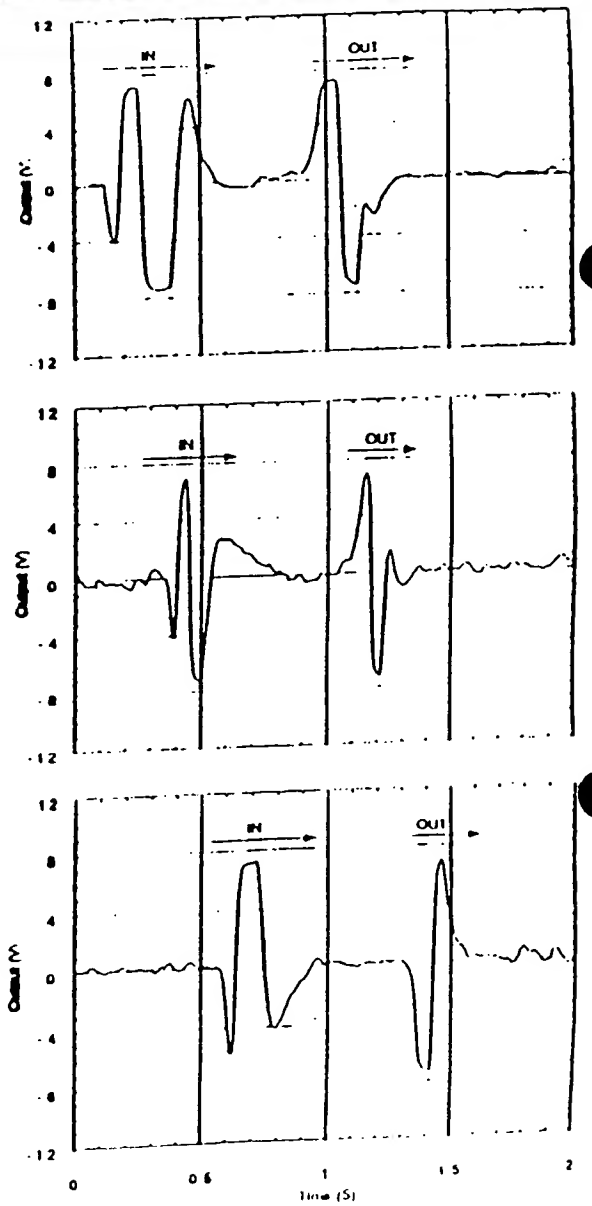
- Plots are a two second time lapse of hand motion in and out of a detection "bubble" at 15" range



No material

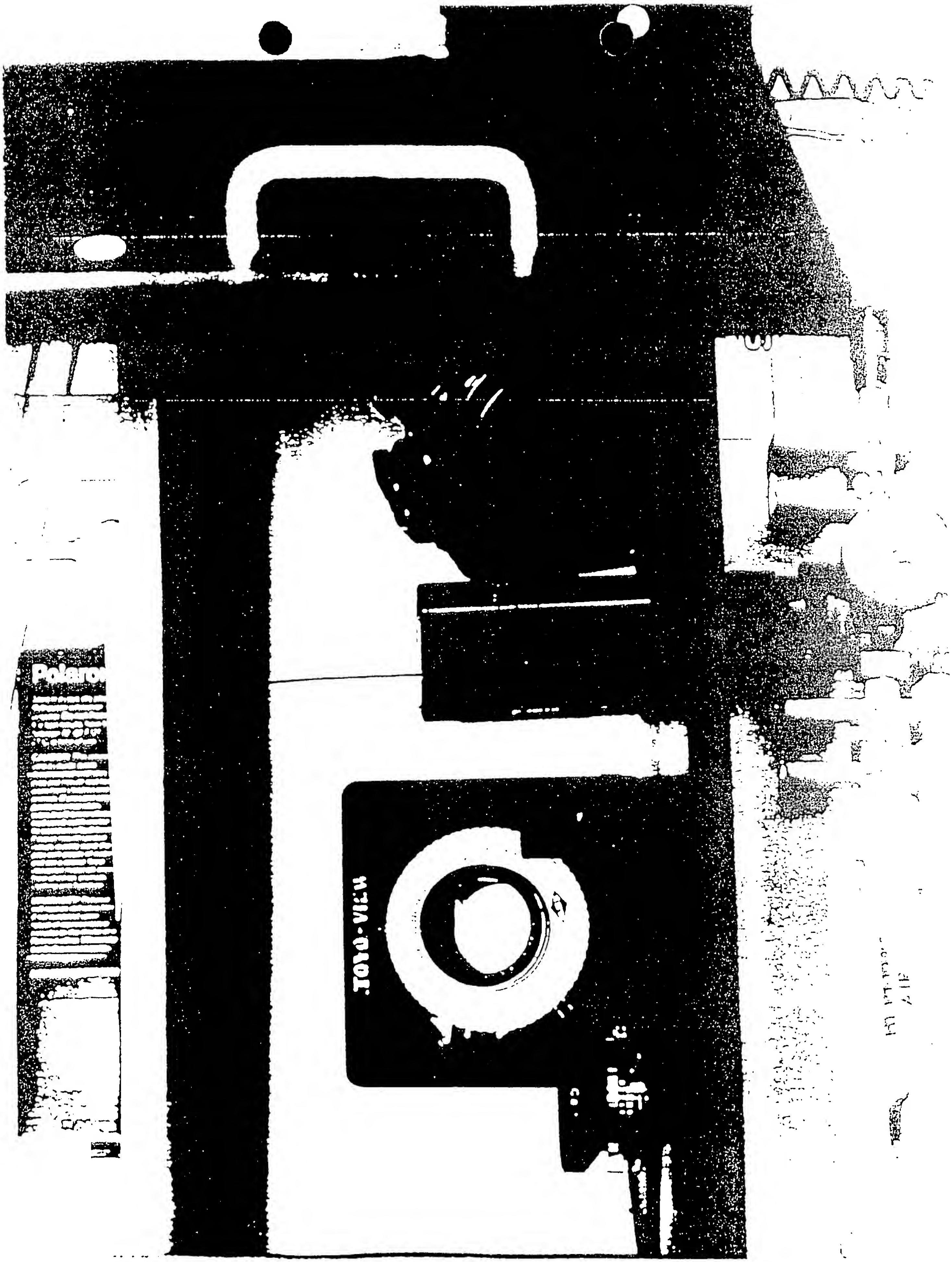
2" concrete slab

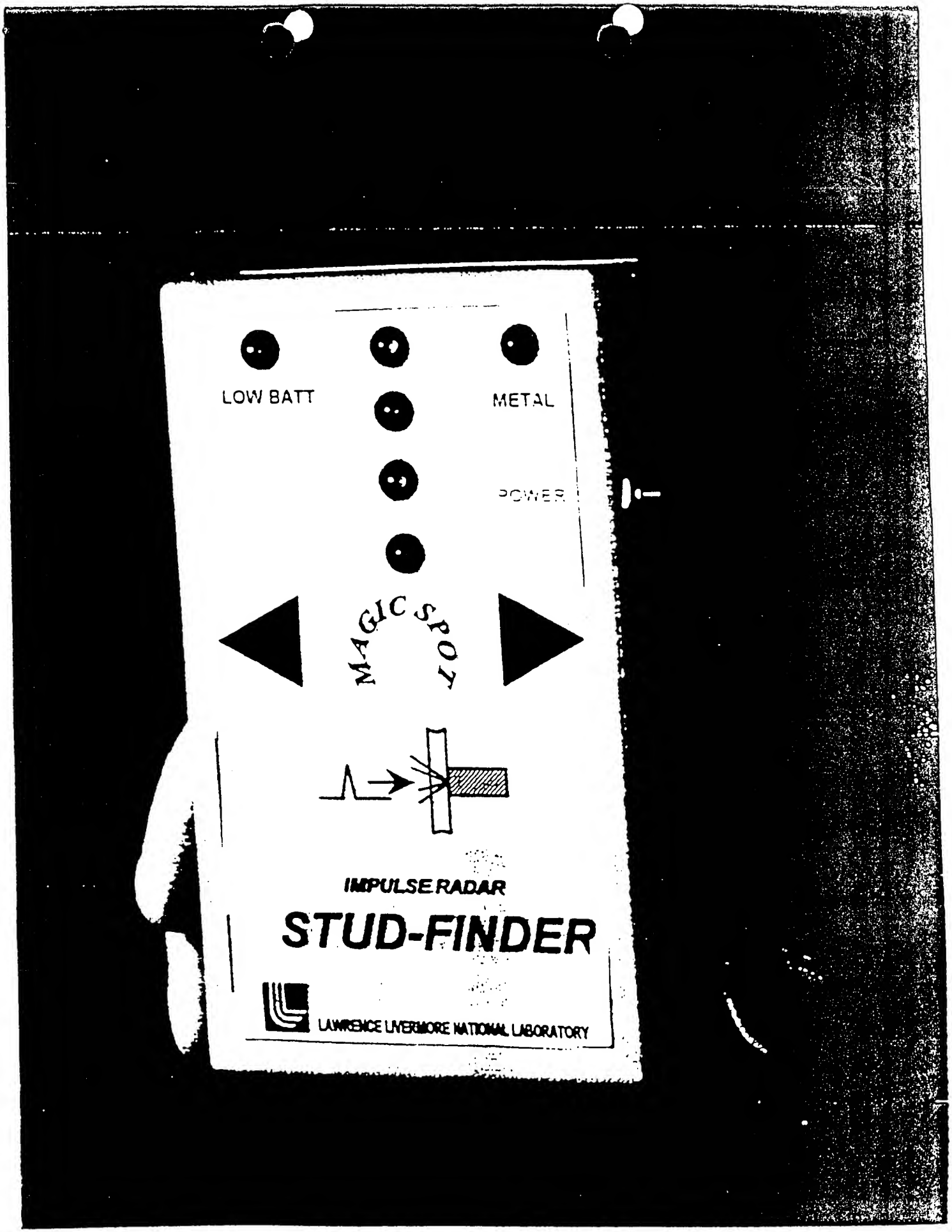
Multiple Textbooks 6" thick



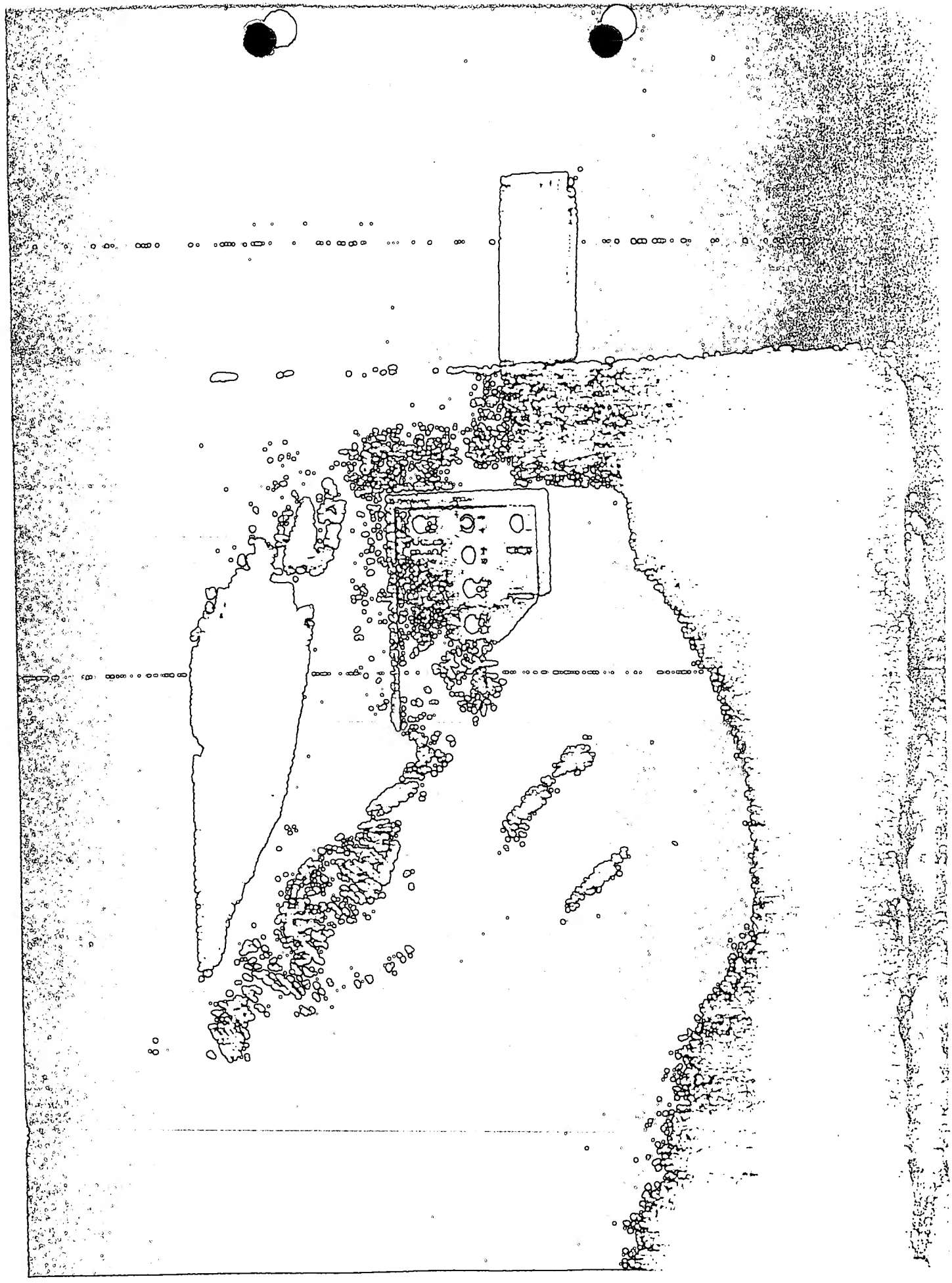
STUDIES

Radar
Fig. 2


TOYO-VIEW


LOW BATT
METAL
POWER
MAGIC SPOT
IMPULSE RADAR
STUD-FINDER
LAWRENCE LIVERMORE NATIONAL LABORATORY

Radar



Radar